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Process for reducing the aldehyde concentration in a mixture comprising
cyclohexanone and one or more aldehydes

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PROCESS FOR REDUCING THE ALDEHYDE CONCENTRATION IN A MIXTURE
COMPRISING CYCLOHEXANONE AND ONE OR MORE ALDEHYDES

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The invention relates to a process for reducing the aldehyde concentration in a mixture comprising cyclohexanone and one or more aldehydes.

Such a process is known from GB-A-2028329. This patent publication describes that aldehydes like caproaldehyde (hexanal) can be removed by subjecting a mixture comprising cyclohexanone and aldehydes to an aldol condensation reaction carried out in a separate aldol condensation vessel in the presence of an aqueous sodium hydroxide solution. The so-obtained mixture is subsequently washed with water. In order to improve phase separation, cyclohexane is fed to the washing device. The washed organic mixture is subsequently distilled in a distillation column where low boiling components are distilled off. It has been found that omitting such treatment would result in cyclohexanone which does not meet the demands normally required for its use, mainly because the cyclohexanone contains a too high amount of aldehydes which could hardly be separated under conventional distillation conditions.

A disadvantage of the process as described in GB-A-2028329 is that a separate aldol condensation reaction vessel and a washing device are needed. Another disadvantage is that in case the washing is effected in the presence of cyclohexane, cyclohexane has to be removed from the washed mixture.

The object of the present invention is to provide a simple and efficient process for removing aldehydes from cyclohexanone.

This object is achieved in that the process comprises distilling the mixture comprising cyclohexanone and one or more aldehydes in a distillation column in the presence of an alkaline compound, wherein in the bottom of the distillation column substantially no water is present.

It has been found that with the process of the invention cyclohexanone can be obtained with a purity with respect to aldehydes which is at least comparable to the purity of the cyclohexanone as obtained in the process as described in GB-A-2028329. The cyclohexanone obtained with the process of the invention is suited as a raw material for the production of caprolactam with a high quality. An advantage of the process of the invention is that a separate aldol-condensation reaction vessel and a washing device are not necessary. An additional advantage is that water and optionally cyclohexane which is/are added in the washing step does/do

not have to be removed. This is advantageous because less process equipment is necessary and less energy is necessary to obtain cyclohexanone with sufficient purity with respect to aldehydes.

Aldehydes may be for example formed during the preparation of cyclohexanone. Examples of aldehydes are butanal, pentanal and hexanal. Said aldehydes include aldehydes which could hardly be separated from cyclohexanone under conventional distillation conditions. Aldehydes which could hardly be separated under conventional distillation conditions in particular concerns pentanal and hexanal. It has been found that the presence of these aldehydes, and especially the presence of pentanal and hexanal, in cyclohexanone is undesired. In particular when cyclohexanone having a too high concentration of pentanal and hexanal (relative to the mixture comprising cyclohexanone, hexanal and/or pentanal) is processed into polycaprolactam (nylon-6) by oximation, Beckmann rearrangement and polymerization, the mechanical strength of the polycaprolactam obtained may be decreased to an undesired extent. When such cyclohexanone is processed into polycaprolactam, the aldehydes and especially pentanal and hexanal, even if present in low concentrations, give rise to impurities with a highly deleterious effect on the strength of the polycaprolactam. It has been found that the concentration of pentanal and hexanal in cyclohexanone is preferably lower than 90 weight ppm (relative to the mixture comprising cyclohexanone, pentanal and hexanal). The present invention therefore also relates to a process for preparing caprolactam by converting cyclohexanone comprising less than 90 weight ppm pentanal and hexanal into cyclohexanone oxime and by Beckmann rearranging of cyclohexanone oxime into caprolactam. The term weight ppm (parts per million) pentanal and hexanal is understood to mean the ratio of grams of the pentanal and hexanal per one million gram of a mixture comprising cyclohexanone, pentanal and/or hexanal.

In the process of the present invention, it is essential that in the bottom of the distillation column, in which the mixture comprising cyclohexanone and one or more aldehydes is distilled, no or substantially no water is present. As used herein substantially no water refers to less than 100 weight ppm of water (relative to the bottom product, i.e. the mixture present in the bottom of the distillation column). The term weight ppm (parts per million) water is understood to mean the ratio of grams of water per one million gram of bottom product. It has surprisingly been found that when the distilling is performed in the presence of more than 100 weight ppm of water in the bottom, the amount of aldehydes and in particular the amount of pentanal and hexanal is not sufficiently decreased in the process of the invention. In particular, it has surprisingly been found that when the distilling is performed in the presence of more

than 100 weight ppm of water in the bottom, the amount of aldehydes and in particular the amount of pentanal and hexanal is not decreased in the process of the invention to such an extent that the ultimately obtained cyclohexanone comprises less than 90 weight ppm pentanal and hexanal.

5 The process of the present invention is performed in a distillation column. The column may be any suitable distillation column. Examples of suitable distillation columns are tray columns or columns filled with a random or structured packing. As used herein the bottom of a distillation column refers to the zone in which the liquid phase is present which is the most rich in high-boiling components, for
10 example, the reboiler zone and the zone below the lowest tray for a tray distillation column and the reboiler zone and the zone below the packing for a distillation column filled with a packing.

 The mixture comprising cyclohexanone and aldehydes which is distilled in the process of the invention can be obtained with various known processes.
15 The mixture usually comprises more than 200 weight ppm of aldehydes and less than 6000 weight ppm of aldehydes (relative to the mixture). The mixture usually comprises more than 500 weight ppm and less than 5000 weight ppm pentanal and hexanal (relative to the mixture).

 The mixture can, for example, be obtained by oxidation of
20 cyclohexane in the liquid phase with molecular oxygen or a molecular oxygen containing gas in the presence or absence of an oxidation catalyst. In one embodiment of the invention, the mixture is obtained by oxidizing cyclohexane in the absence of an oxidation catalyst resulting in a mixture comprising cyclohexane, cyclohexyl hydroperoxide, cyclohexanone and cyclohexanol and subsequently treating this
25 mixture with a cyclohexyl hydroperoxide-decomposing salt in the presence of an aqueous solution of an alkali metal hydroxide to form cyclohexanol and cyclohexanone. The mixture obtained after decomposition of cyclohexyl hydroperoxide contains, in addition to the cyclohexanone, a considerable amount of the corresponding cyclohexanol in most instances, and minor proportions of low boiling and high boiling
30 components. In another embodiment of the invention, the mixture is obtained by oxidizing cyclohexane in the presence of an oxidation catalyst resulting in an oxidation mixture comprising cyclohexane, cyclohexanone and cyclohexanol and minor amounts of low and high boiling compounds. With low boiling compounds is meant compounds having a boiling point lower than cyclohexanone and higher than cyclohexane.
35 Examples are butanol, pentanal, hexanal, pentanol and epoxy cyclohexane. With high boiling compounds is meant compounds having a boiling point higher than cyclohexanol. Examples are 2-cyclohexylidene cyclohexanone, 2-hexylidene

cyclohexanone and 2-(cyclohexen-1-yl)cyclohexanone. The oxidation mixture or mixture obtained after decomposition is usually processed by first distilling off cyclohexane and the by-products that are more volatile than the cyclohexane, followed by distilling off low boiling compounds, subsequently cyclohexanone and finally the cyclohexanol. Cyclohexanol may subsequently subjected to a dehydrogenation reaction using a dehydrogenator. Preferably, the process of the present invention is performed in the distillation column in which low boiling components are distilled off from a mixture containing cyclohexanone, cyclohexanol, and high boiling compounds. A preferred embodiment of the present invention therefore relates to a process to distill off low boiling components including hexanal and/or pentanal from a mixture also containing cyclohexanone, cyclohexanol and high boiling compounds in the presence of an alkaline compound in a distillation column in which in the bottom no or substantially no water is present. Usually, the mixture which is fed to the distillation column in which low boiling components are distilled off, comprises between 40 and 60 wt.% cyclohexanone, between 40 and 60 wt.% cyclohexanol, between 0.2 and 2 wt.% low-boiling compounds and between 1 and 4 wt.% high boiling compounds and between 200 and 6000 weight parts per million of aldehydes, in particular 500-5000 weight ppm hexanal and pentanal.

The process according to the invention will be described in more detail for this preferred embodiment. It shall be evident that the below stated conditions will also be applicable for the above described mixtures in a manner clear to one skilled in the art.

The distillation is carried out at a top temperature of between 45 and 130 °C and at a bottom temperature of between 105 and 190 °C. The pressure applied at the top of the distillation column is in general between 0.02 and 0.15 MPa.

In the process of the invention, the mixture comprising cyclohexanone and aldehydes is distilled with an effective amount of alkaline compound to lower the concentration of aldehydes and in particular the amount of pentanal and hexanal to such an extent that cyclohexanone with sufficient purity with respect to these components is obtained. Preferably, the mixture comprising cyclohexanone and aldehydes is distilled with an effective amount of alkaline compound to lower the concentration of pentanal and hexanal to such an extent that the concentration of pentanal and hexanal in the cyclohexanone is lower than 90 weight ppm.

The alkaline compound may be introduced in the distillation column in any suitable way, usually as a liquid. Said liquid may be an aqueous solution of said alkaline compound or said liquid may be obtained by introducing the alkaline compound into the mixture prior to feeding the mixture to the distillation column. From a

practical point of view, said liquid is preferably obtained by introducing the alkaline compound into the mixture prior to feeding the mixture to the distillation column. The alkaline compound is preferably an alkali metal compound. Preferred alkaline compounds are alkali metal hydroxide and alkali metal alkoxides. Preferred alkali metal is potassium. In case an alkali metal compound is used, the amount of alkali metal compound introduced in the distillation column or in the mixture prior to feeding the mixture to the distillation column is preferably such an amount that the concentration of alkali metal in the bottom of the distillation column is higher than 2 weight ppm and lower than 50 weight ppm. Using less than 2 weight ppm of alkali metal in the bottom of the distillation column results in that the amount of aldehydes and especially the amount of pentanal and hexanal in the cyclohexanone lowers to a lesser extent. Using more than 50 weight ppm of alkali metal in the bottom of the distillation column results in an increased loss of cyclohexanone.

The alkaline compound is preferably introduced in the distillation column or in the mixture as an aqueous solution of said alkaline compound. Particularly suitable solutions are aqueous solutions of alkali metal hydroxides, alkali metal carbonates, alkali metal alkoxides in particular alkali metal cyclohexanolate. Particularly preferred solutions are aqueous solutions of potassium hydroxide containing from 0.5 to 50 wt.%, more in particular from 5 to 45 wt.% potassium hydroxide. The amount of aqueous solution of potassium hydroxide introduced in the distillation column or in the mixture prior to feeding the mixture to the distillation column is preferably an effective amount to lower the concentration of aldehydes and in particular the amount of pentanal and hexanal to such an extent that cyclohexanone with sufficient purity with respect to these components is obtained.

In particular, the amount of aqueous potassium hydroxide solution introduced in the distillation column or in the mixture prior to feeding the mixture to the distillation column is preferably such that at least 2 weight ppm and more preferably at least 5 weight ppm of potassium is present in the bottom of the distillation column because by using less than 2 weight ppm of potassium in the bottom of the distillation column the amount of aldehydes and especially the amount of pentanal and hexanal in the cyclohexanone lowers to a lesser extent. The amount of aqueous solution of potassium hydroxide introduced in the distillation column or in the mixture prior to feeding the mixture to the distillation column is preferably such that that the amount of potassium in the bottom of the distillation column is not higher than 50 weight ppm and more preferably not higher than 40 weight ppm and even more preferred not higher than 35 weight ppm because it has been found that the use of more than 35 weight

ppm of potassium in the bottom of the distillation column results in an increased loss of cyclohexanone.

The alkaline compound may be introduced in the mixture prior to feeding the mixture to the distillation column or it may be introduced to the distillation column. Preferably, the alkaline compound is introduced to the distillation column at the point where the mixture to be distilled in the distillation column is fed or in the zone below this point because this results in a decrease of cyclohexanone loss. From a practical point of view, the alkaline compound is preferably present in the mixture which is fed to the distillation column.

It has been found that in case the alkaline compound is introduced to the distillation column as an aqueous alkaline solution, the aqueous alkaline solution is advantageously fed to the distillation column at a level above the bottom of the distillation column such as to obtain that substantially no water is present in the bottom of the distillation column. In case a tray distillation column is used, the aqueous alkaline solution is advantageously fed to or above the first (numbered from the bottom of the distillation column to the top) tray of the distillation column.

The process of the invention will now be further elucidated with the following non-limiting examples.

Experiment A

A mixture, comprising cyclohexanone, cyclohexanol and low and heavy boiling compounds was fed to a first distillation column at a rate of 25 m³/hr. Pentanal and hexanal concentrations in the mixture were 70 and 300 weight ppm respectively. The mixture was fed to the 23rd tray of the total 60 sieve trays (trays numbered from bottom to top). The column was operated at 0.08 MPa and 121°C at the top of the column and about 0.1 MPa at tray with number 20 and 165°C at the bottom of the column. 14 t/h steam (1.25 MPa) was applied in the reboiler. Low boiling products, such as n-butanol, n-pentanol, hexanal and epoxy cyclohexane were separated off via the top of the column. An aqueous solution of 5 wt% KOH was added to the bottom of the distillation column at a rate of 50 ml/min, resulting in a water concentration of 150 weight ppm and a potassium concentration of 5 weight ppm in the bottom product. The bottom product was withdrawn from the distillation column and mixed with a 25 m³/hr mixture of cyclohexanone, cyclohexanol and heavy boiling components. This mixture was fed to the top of a second distillation column. The second column is a packed column and operates at approximately 74°C at the top of the column; and 10.7 kPa at 103°C at the bottom of the column. Cyclohexanol and heavy boiling components left the bottom of the second distillation column. The

pentanal and hexanal concentrations in the top product (mainly comprising cyclohexanone) were 12 and 130 weight ppm respectively. Concentration of CHIA (2-cyclohexylidene cyclohexanone which is a dimer of cyclohexanone) in the bottom of the first distillation column was 0.1 wt.%, indicating that product losses due to dimerization of cyclohexanone were small.

Comparative Experiment B

Experiment A was repeated with the difference that pentanal and hexanal concentrations in the feed of the first distillation column were 400 weight ppm and 2100 weight ppm. No aqueous KOH solution was fed to the first distillation column. The pentanal and hexanal concentrations in the top product (mainly comprising cyclohexanone) of the second column were 20 and 190 weight ppm respectively (relative to the cyclohexanone present in the top product). Concentration of CHIA (2-cyclohexylidene cyclohexanone) in the bottom of the first distillation column was 0.1 wt.%, indicating that product losses due to dimerization of cyclohexanone were small.

Experiment C

A mixture of cyclohexanone, cyclohexanol, low and heavy boiling compounds, 400 weight ppm pentanal and 2100 weight ppm hexanal, was treated with 2.5 m³/hr NaOH solution, having an alkalinity of 2 meq/g, in a stirred saponification vessel at a rate of 25 m³/hr at 103 °C during 15 minutes. The resulting mixture was mixed with 20 m³/hr cyclohexane and sent to a separation vessel to separate the aqueous phase. The organic mixture was countercurrently washed in a packed column with 7 m³/hr water to extract the water droplets containing sodium. The washed organic mixture was sent to the top of a drying column to remove cyclohexane and water. The drying column had 15 sieve trays and was operated at a pressure of about 0.1 MPa, a top temperature of about 78°C, and a bottom temperature of about 161 °C. Pentanal and hexanal concentrations in the bottom product of the drying column were 70 and 300 ppm. Comparative Experiment B was repeated with this bottom product as feedstock, resulting in pentanal and hexanal concentrations in the top product of the second column of 6 and 60 weight ppm respectively (relative to the cyclohexanone present in the top product). Concentration of CHIA (2-cyclohexylidene cyclohexanone) in the bottom of the first distillation column was 0.1 wt.%, indicating that product losses due to dimerization of cyclohexanone were small.

Example I

Comparative Experiment A was repeated with the difference that the

50 ml/min 5wt.% KOH solution was fed in the feed pipe of the first distillation column. Potassium concentration in the bottom was 5 weigth ppm (hereinafter referred to as ppmw) and the water concentration in the bottom was <10 ppmw. The pentanal and hexanal concentrations in the top product of the second column were 4 and 50 ppmw respectively (relative to the cyclohexanone present in the top product). Concentration of CHIA (2-cyclohexylidene cyclohexanone) in the bottom of the first distillation column was 0.07 w%.

Comparison of Example I with Experiment C indicates that with the process of the invention cyclohexanone with an even increased purity with respect to pentanal and hexanal can be obtained in a very simple manner.

Example II

Example I was repeated with the difference that the KOH solution flow rate was increased to 70 ml/min. Potassium concentration in the botttom was 7 ppmw and water concentration in the bottom was <10 ppmw. The pentanal and hexanal concentrations in the top product of the second column were 2 and 15 ppmw respectively (relative to the cyclohexanone present in the top product). Concentration of CHIA (2-cyclohexylidene cyclohexanone) in the bottom of the first distillation column was 0.10 wt%.

Example III

Example I was repeated with the difference that the KOH solution flow rate was increased to 350 ml/min. Potassium concentration in the bottom was 35 ppmw and water concentration in the bottom was <10 ppmw. The pentanal and hexanal concentrations in the top product of the second column were 1 and 5 ppmw respectively (relative to the cyclohexanone present in the top product). Concentration of CHIA (2-cyclohexylidene cyclohexanone) in the bottom of the first distillation column was 0.35 wt%.

CLAIMS

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1. Process for reducing the aldehyde concentration in a mixture comprising
cyclohexanone and one or more aldehydes, said process comprising distilling
said mixture in a distillation column in the presence of an alkaline compound,
wherein in the bottom of the distillation column substantially no water is
present.
2. Process according to claim 1, wherein the mixture is a mixture comprising
cyclohexanone, cyclohexanol, low boiling compounds and high boiling
compounds and the mixture is treated in a distillation column in which low
boiling compounds are distilled off.
3. Process according to claim 1 or 2, wherein the aldehydes are hexanal and/or
pentanal.
4. Process according to claim 2 or 3, wherein the distillation is effected at a top
temperature of between 45 and 130 °C and a bottom temperature of between
105 and 190 °C.
5. Process according to any one of claims 1-4, wherein the alkaline compound is
an alkali metal compound.
6. Process according to claim 5, wherein distilling the mixture is effected with
such an amount of alkali metal compound that the concentration of alkali metal
in the bottom of the distillation column is higher than 2 weight ppm and lower
than 50 weight ppm.
7. Process according to any one of claims 1-6, wherein the process comprises
introducing an aqueous alkaline solution to the distillation column at a level
above the bottom of the distillation column.
8. Process according to any one of claims 1-7, wherein the process comprises
introducing an aqueous alkaline solution into the mixture prior to feeding the
mixture to the distillation column.
9. Process according to claim 7 or 8, wherein the aqueous alkaline solution is an
aqueous alkali metal hydroxide solution.
10. Process according to claim 9, wherein the aqueous alkali metal hydroxide
solution is an aqueous potassium hydroxide solution.
11. Process for preparing caprolactam by converting cyclohexanone into
cyclohexanone oxime and converting said cyclohexanone oxime into
caprolactam, wherein the total amount of hexanal and pentanal in said
cyclohexanone is lower than 90 weight ppm hexanal and pentanal (relative to
cyclohexanone).

ABSTRACT

- 5 The invention relates to a process for reducing the aldehyde concentration in a mixture comprising cyclohexanone and one or more aldehydes, said process comprising distilling said mixture in a distillation column in the presence of an alkaline compound, wherein in the bottom of the distillation column substantially no water is present.

PCT Application
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